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# EXPERIMENTAL EPIDEMIOLOGY[1]

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EPIDEMIOLOGY, according to common usage, is knowledge of the mode of spread of infectious diseases. This knowledge is especially concerned with epidemics and endemics, long-time and short-time cycles of disease prevalence, general and local extension of disease and relative severity of disease in racial and familial groups and in individuals. Data, mostly descriptive and poorly organized, accumulating for centuries, were simplified in part by experimental pathologists and bacteriologists at the close of the nineteenth century into several principles, a postulate and a theory.

Considered chronologically, the first two principles are the communicability of certain diseases and the living specific nature of their known incitants. This knowledge was present in substance 4,000 years ago in popular superstitions and beliefs but was not established on an experimental basis until Bassi transmitted silkworm muscardine in 1835, Remak transmitted favus in 1840, and Brauell, Pasteur, and Koch transmitted anthrax in 1857 to 1890. Three additional principles, namely, the operation of host resistance, diet and climatic factors influencing the spread of infectious disease, were likewise recognized from earliest times, but are only recently being studied experimentally. The last two, the doctrines of the carrier state and of specific immunity, established by Koch and by Behring and Kitasato, respectively, are modern both in concept and experimental proof.

Knowledge of infection underwent further organization during the Pasteur-Koch period. Theurgical and supernatural doctrines of epidemics were dis-

[1] Cutter Lecture on Preventive Medicine, 1932. Harvard University.

carded, and the possible effects of cosmic, constitutional and subsoil influences came to be ignored. In their places a postulate was made by students of descriptive epidemiology, that all phenomena of infection can be accounted for in terms of three factors—virulence of the specific agent, dosage of the agent available to the host and resistance of the host to the specific agent. This postulate has since been accepted by the majority of epidemiologists.

Strangely enough, however, except for the studies of Theobald Smith and of plant pathologists, few efforts have been made to test the postulate experimentally, or to analyze the mode of operation of the hypothecated microbic and host factors. The descriptive epidemiologist is working with vital statistics which contain uncontrolled sources of error, the bacteriologist is studying the problem of microbic virulence in artificial infections and in artificial media, without determining whether his findings are in any way related to the behavior of microorganisms in their native host, and the immunologist is gaining knowledge of the specific substances found in the blood of individuals who have been exposed to an antigen, but is slow to investigate the extent to which these specific substances are related to the resistance of the host under natural conditions.

The postulate of the rôle of parasite-host factors was, in spite of the lack of experimental testing, further simplified by bacteriologists and immunologists into a theory that the spread of infectious disease is determined in the main by fluctuations in virulence of the specific agent and fluctuations in the specific acquired immunity of the host. This prevailing view has of late, however, been subjected to much criticism. Some investigators urge that bacteriology alone does not explain all the mass phenomena of epidemics and consequently that unknown forces should be given further consideration. Others believe that more attention should be paid to the demonstrable phenomena of host, climate and dietary influences. Increasing numbers regard epidemiology as not reducible to bacteriology and immunology alone, and demand a type of investigation which deals with conditions more closely similar to those in nature.

To meet this need, a new field of research has been developed. Shortly after the influenza pandemic of 1918–1919, investigations were commenced by Topley in London and by Flexner and Amoss in New York, to determine experimentally the general mechanisms underlying the spread of infectious disease. These studies, continued and amplified by others in the past eleven years, have come to be regarded as a definite discipline—experimental epidemiology.

This discipline is far-reaching in scope. It affords a means of acquiring relevant and at the same time controlled data on the spread of one or a number of animal infections. It affords a hope that this sort of information of a number of infections in a number of species of native hosts may be simplified into a theory which will describe a part of the epidemiology of animal and of human infections as well.

The technique of experimental epidemiology has been to study the mode of spread of native infections among populations of laboratory animals. Thus far a total of nine enteric and respiratory infections of rodents and fowls has been analyzed by observations both on population infections occurring spontaneously, and induced experimentally, and by measurements of virulence, dosage and host resistance, especially during the actual spread of infection. The technique has been put to use in two different ways. Topley and Greenwood experiment with *aertrycke* infection of mice chiefly to throw light directly on the perplexing questions of human epidemiology; we, on the other hand, study the spread of an animal infection as an end in itself and extend the study to different native infections in different host species with a view to building up an experimental science. The details of the technique have differed according to the emphasis placed upon control of variables and adherence to natural conditions. Some investigators have made relatively few efforts in their experiments to control host variables and in many instances to reproduce natural conditions. Their efforts have rather taken the direction of attempting to interpret data by subjecting them to the ordinary analyses used in the study of vital statistics.

It is to be assumed, however, that since one or many factors may conceivably influence the spread of infection, the greatest possible control of all is to be desired. Therefore, in recent experiments at the Rockefeller Institute every effort has been made to control not only the microbic but especially the host variables. The animals employed are born and raised in special breeding rooms on the premises. Their heredity, age and weight are known; their allotted space, cleaning routine, food, temperature and light are kept uniform. The animals are known to have been free of any previous exposure to the given infection. Finally, when microbic virulence, dosage and host resistance factors are being analyzed, it is to be assumed that a technique reproducing natural conditions in the greatest degree is most apt to yield results which are applicable to the phenomena of natural infection. Hence, in the institute laboratories the specific bacteria are introduced into the native hosts not by intraperitoneal injection but by way of the normal portal of entry. These procedures

e results which reproduce events in nature and ich at the same time are quantitative.

Early experiments showed that natural infection ld be established in susceptible populations by ministering pure cultures of specific bacteria to nstituents or immigrants. Amoss, in 1922, fed ouse typhoid cultures to ten mice and placed them two cages in the midst of 100 normal mice in enty cages. Shortly thereafter, the specific infecn was fatal to eight of the original mice and spread the normal animals. Later, four batches of mice ere added and the infection extended to each group turn. Recently Friedländer pneumonia was esblished in four populations of mice in our laborary by administering 500 bacilli intranasally to cerin constituents—in one experiment the entire group ceived the organisms and normal immigrants were dded thereafter at the rate of two per day for three nd a half years; in two further experiments three roups of 100 mice each received six immigrant mice hich had been given 500 Friedländer bacilli inranasally. Healthy immigrants were added thereafter for two and a half years and eight months, repectively. In each case the Friedländer infection pread from the immigrants to the healthy population nd became established with endemic and epidemic hases identical with those of the spontaneous disease.

Early experiments likewise showed that epidemics could be induced in populations under two definite sets of conditions. First, in previously unexposed communities, by administering to each individual a certain dose of the specific organisms by way of the natural portal of entry, and second, in already infected populations, by adding susceptible immigrants. Epidemics of mouse typhoid were incited in previously unexposed populations by administering three to five million bacilli in broth intrastomachally to batches of 20 to 100 mice. The resulting mortality over a sixty-day period in averaged tests was characteristic and practically identical with that occurring during spontaneous epidemics. Epidemics of Friedländer pneumonia were incited in previously unexposed populations by administering 500 bacilli in broth intranasally to batches of 50 to 100 mice. The resulting mortality over a thirty-day period was uniform in averaged tests and similar to that occurring during spontaneous epidemics. In infected populations, outbreaks of mouse typhoid were incited by adding batches of normal susceptible immigrants. Following some suggestive observations of Topley in 1919, Amoss assembled 100 healthy mice in twenty cages of five mice each and midway placed two additional cages of five mice each, which had been fed on a culture of mouse typhoid bacilli. Four weeks later forty additional cages, containing five mice each, were placed near the first batch. Subsequently, sporadic infection occurred, fatal in three months to about 50 per cent. of the population. The survivors were recruited to their original numbers by replacements in each cage to five mice. Within a few days an epidemic of mouse typhoid occurred, fatal to 70 per cent. of the herd in two months. A second and third replacement was made, followed by outbreaks of decreasing severity. These results were confirmed in 1925 by Greenwood and Topley, who showed that the repeated addition of normal individuals to mouse populations infected with Pasteurella is followed by recurring epidemic waves. Likewise, experiments at the Rockefeller Institute in 1930 showed that if immigrants were added to one of three mouse populations infected with *B. friedländeri*, recurrent epidemics of pneumonia ensued, while if at the same time and under identical conditions, immigrations were discontinued in two remaining populations, no epidemics occurred and the infection died out.

Topley and Greenwood, in further observations on infected mouse populations, emphasized the close association between the amount of mortality and the number of susceptible immigrants. They found that when mice were added to an infected herd at a constant rate, the mortality was propagated in regularly recurring waves and suggested that the character of the waves was dependent upon the rate of addition of immigrants. We observed later that when four or more populations of mice infected with *B. friedländeri* were recruited at the rate of two mice per day, the primary epidemic waves of pneumonia occurred when the population had reached a certain level, lasted a definite number of days, and reduced the population census to a definite low level. Moreover, when *B. enteritidis* typhoid was spreading under identical conditions in uncomplicated form in these communities, the mortality waves occurred with considerable regularity at nine to eleven day intervals. It is concluded, therefore, that epidemics may be incited in already infected herds by the proper addition of susceptible immigrants, and in unexposed populations by administering to each individual a certain dose of the specific organisms.

Early in these studies, Topley observed that, following epidemics of mouse typhoid there are a certain number of survivors and stated that these survivors are both potentially infective and relatively immune. Evidence of the immunity of survivors was obtained later in our laboratory by actually comparing the resistance of surviving and non-exposed mice. Mouse typhoid organisms were administered by mouth to 100 individuals; sixty days later there were thirty-two survivors. These together with twenty normal,

unexposed mice, were then given a similar dose of bacteria. Sixty days later, 30 per cent. of the survivor group had succumbed, as compared to 80 per cent. of the control group, showing that by actual test survivors are more resistant than non-exposed animals to the given infection.

The results thus far described demonstrate that various endemic and epidemic phenomena of natural enteric and respiratory infections may be reproduced experimentally solely by the proper bringing together of susceptible hosts and pathogenic microorganisms, thus furnishing experimental evidence for the postulate brought forward by followers of the Pasteur-Koch school fifty years ago. The second accomplishment of these experiments has been to afford an opportunity for analyzing the microbic and host factors under natural and yet controlled conditions, that is, to determine whether virulence does vary during epidemics and whether epidemics are brought to an end by the population acquiring a specific immunity.

Attention will be first given to the virulence factor. That the virulence of a microorganism, that is, its capacity to harm its native host, is a highly labile variable is an assumption founded upon the early observations of Davaine and Pasteur. This idea, supported later by bacteriologists, has come to form the basis of modern epidemic theory. The experimental epidemiologist, however, recognizing that the data are derived from tests which are now regarded as inadequate, has interested himself in the potency of bacteria under conditions as nearly natural as possible.

One series of tests showed that typical strains of organisms from infected animals were of uniform virulence, whether recovered early or late in the course of disease. For example, each of two cultures of mouse typhoid organisms were given intrastomachally to twenty mice, one from the heart's blood of an animal dying five days after exposure to mouse typhoid; the other from the tail vein of a mouse with septicemia, surviving the infection for five weeks. The acute septicemic culture proved fatal to fourteen; the chronic septicemic culture to twelve mice.

Other tests showed that strains of mouse typhoid, Friedländer and fowl cholera organisms from healthy carriers were in general of the same virulence as strains recovered from fatal cases. Thus, each of three strains of *aertrycke* mouse typhoid organisms was given by mouth to twenty mice, one a culture from an acute septicemic case, two others from stools of two mice surviving and healthy five weeks after exposure. The mortalities were 70, 70 and 65 per cent., respectively. Tests with *B. enteritidis* mouse typhoid gave similar results. Several strains of mouse Friedländer organisms were administered intranasally to batches of fifty or 100 mice in comparable doses. In one instance, a lung culture from fatal case was compared with a culture obtained from a healthy carrier. Each was given to 100 mice intranasally. The resulting mortalities were 70 and 65 per cent., respectively. Tests were made with thirty fowl cholera strains from fatal cases and forty strains from healthy carrier fowl on several commercial farms. Each strain was administered into the nasal cleft of twenty specially bred young birds. In general, strains from fatal cases proved to be of the same virulence as similar strains from healthy carriers.

Further experiments indicated that strains of specific organisms recovered from populations at various endemic and epidemic periods of spontaneous infection were of uniform virulence. Epidemics of fowl cholera and rabbit-snuffles pneumonia, mouse typhoid and mouse pneumonia were studied in our laboratory, epidemics of guinea-pig and rabbit Pasteurella and pneumococcus pneumonia by Neufeld in Berlin, and epidemics of guinea-pig typhoid by Theobald Smith at Princeton. In no instance were significant differences in the virulence of pre-epidemic, epidemic and post-epidemic strains detected.

Still other tests showed that strains of the same organisms from different populations may differ in virulence and in general that the strains with high potency for killing the native host possessed relatively little ability to vegetate in the tissues of survivors and *vice versa*. This latter relationship is illustrated by experiments in which an epidemic or endemic strain of fowl cholera organisms was administered intranasally to young chickens and permitted to spread to healthy contacts. The tendency of the epidemic strain to kill but not to spread, in contrast to the tendency of the endemic strain to spread but not to kill, was consistent. The same differences were demonstrable with epidemic and endemic strains of rabbit Pasteurella.

One further series of tests may be mentioned briefly—namely, those of the effect of animal passage on virulence. Since the early days of bacteriology, cultures have been transferred from animal to animal for the purpose of enhancing their virulence. The tests have been made for the most part in some foreign animal host and by means of some artificial method, such as intraperitoneal injection, and the results, although definite in a few instances, have usually proved equivocal. Nevertheless, they have been employed to support the idea that prior to an epidemic the virulence of the specific agent increases by means of passage from host to host. The present tests were made under conditions as nearly natural as possible. Mouse typhoid organisms from heart's

ood or intestinal contents of animals in the acute ages of infection were given intrastomachally to tches of mice without intermediate cultivation on tificial media. Such passages were made serially d repeatedly. Similar tests were made with Pasurella cultures native to rabbits, and fowl cholera ganisms native to chickens. In no instance was a gnificant increase in virulence demonstrable.

In summary, the effective virulence of a given rain of microorganisms, when analyzed under atural and controlled conditions, has proved to be relatively stable property and to some extent inersely related to its ability to survive in the tissues f its natural host. The virulence of numbers of trains of the same organism in the same community as uniform, while the virulence of strains from diferent communities was at times dissimilar.

The second epidemic factor to be analyzed was microbic dosage—the number of organisms available o the individual host or to the total population at given time. The findings may be summarized as ollows. Changes in dosage exerted a direct effect pon mortality, when virulence and resistance were onstant. As dosage was increased, there ensued a progressive increase in percentage mortality up to a oint less than 100 per cent. Thus, in a titration of mouse Friedländer bacilli, each of eight doses of he organisms given intranasally to twenty-five mice esulted in mortalities of 32, 44, 56, 64, 88, 96 and 96 per cent., respectively. The second finding has been referred to before, namely, that by giving mice proper doses of typhoid or Friedländer organisms, it is possible to reproduce closely the events of explosive, spontaneous epidemics. Finally, it will be pointed out in tests referred to later that during the actual spread of infection in populations, dosage increased prior to epidemics and decreased prior to their decline by a time interval which approximated that of the incubation period of the infection.

Host resistance, the third epidemic factor, was found to be made up of both non-specific and specific components. The non-specific component was present in definite amounts in breeds or races of animals. For example, monthly tests of the resistance of an inbred strain of mice to mouse typhoid organisms were made from 1922 to 1926. The results in terms of mortality were averaged each year and found to approximate each other within 2 or 3 per cent. Similar tests with other enteric and with respiratory infections and tests with other strains of mice gave similar results. The non-specific components of resistance were present in different amounts in different races or breeds. Thus, a black Lathrop strain, pen inbred for twelve generations, proved on nineteen consecutive monthly tests with *B. aertrycke* and several consecutive tests with *B. enteritidis* mouse typhoid to be more susceptible than the Rockefeller Institute mice. Albino Swiss strain mice, also highly inbred, and albino Rockefeller Institute mice were raised on four different diets. In each case the Swiss mice proved more susceptible. Repeated tests with white-faced and black and tan strains, brother and sister inbred, showed them to be more susceptible than the Rockefeller Institute line.

The non-specific component of resistance was also proved to be present in different amounts in individuals of the same breed. Thus, whenever a controlled group of animals is given a definite dose of some harmful agent, such as $HgCl_2$, individuals show markedly different types of response, ranging from death after the briefest interval to a complete refractory state. Again, whenever a group of animals without previous exposure was given a native infection by the normal portal of entry, individuals showed markedly different types of response, ranging from death after the briefest incubation period to a complete refractory state. These differences were the more regular and predictable when every precaution had been taken to insure uniformity of inheritance, environmental conditions and food. In *B. aertrycke* mouse typhoid, for example, when groups of mice were given bacilli intrastomachally, 70 per cent. died with positive blood cultures in a period of five to sixty days, while 30 per cent. survived. Of these latter, about 10 per cent. were recovered cases, with positive agglutinins, while 20 per cent. showed no evidence of infection. Again, when rabbits were given a similar dose of Pasteurella intranasally, 28 per cent. died of pneumonia, of acute interstitial, lobar, or chronic empyema types, 44 per cent. showed merely local rhinitis or sinusitis, 13 per cent. became healthy carriers, and 14 per cent. remained uninfected. Similar quantitative effects followed the administration of fowl cholera organisms to chickens. These findings have been confirmed by workers in Neufeld's laboratory in their studies of Friedländer and pneumococcus infections of mice. In short, individuals submitted to precisely the same risk of infection, under identical conditions, where every known factor was controlled, exhibited profound differences in response.

That these differences in the reaction of individuals are due to amounts of non-specific resistance which are inherited was shown by the results of tests on survivors and by breeding experiments. Thus, mice surviving an intrastomachal instillation of mouse typhoid organisms proved more resistant to an instillation of mercury bichloride than normal mice. Most significant, however, is the fact that the progeny of mice surviving *aertrycke* or *enteritidis* typhoid were

more resistant to subsequent infection with mouse typhoid bacilli or to doses of mercury bichloride than normal, unselected mice; and conversely, progeny of mice, succumbing early to typhoid, were more susceptible than unselected mice. A further study of the inheritance of different degrees of susceptibility is now in progress. Five hundred female and one hundred male mice of the Rockefeller Institute strain were mated, one male to five females. When the young were weaned, the six hundred parents were given intrastomachally three million *enteritidis* mouse typhoid bacilli. In cases in which both parents died within ten days after infection and in which, on the other hand, both parents survived sixty days, the respective litters from susceptible and resistant parents were saved for further breeding. Simultaneous tests of resistance have since been made on progeny of six generations of the original susceptible and resistant group together with an unselected control group. The possibility of specific immunity developing from infected animals was definitely ruled out by repeated carrier and autopsy tests, by testing the population for carriers, by testing animals found dead for mouse typhoid organisms, and by housing the progeny of susceptible and resistant lines together in the same cage for four weeks. The stock has remained free of all infection. Thus far, five lines of susceptible mice and six lines of resistant mice have been selected. The susceptible lines show approximately 95 per cent. mortality within fifteen days after exposure; the control group shows 35 to 40 per cent., and the resistant lines show approximately 5 per cent. mortality over the sixty-day period of observation. The same relationship holds when the resistant mice are given ten times the dose and the susceptible mice 1/100 of the standard dose. The final and necessary test of the resistance of these mice was their response to exposure to spontaneous infection. Cages were arranged to contain five unselected mice given five million *B. enteritidis* per os, together with five normal mice from the susceptible lines and five from the resistant lines. In each instance, all or nearly all the contact susceptible mice contracted the infection and died, while all or nearly all the resistant mice survived and remained healthy. These results prove that of five hundred individuals selected at random, some possess a greater and some a less amount of resistance to *B. enteritidis*, which is transmitted quantitatively to their progeny.

Non-specific components of resistance, besides being inherited, are affected by environmental factors such as season and diet. Thus, each month over a period of years, batches of 50 to 100 mice have been given mouse typhoid or Friedländer organisms with the result that mortalities, although irregular, have been definitely greater during the winter than the summer seasons. Again, mice raised on various adequate diets differed markedly in resistance. One diet containing bread and milk has sufficed to raise the Rockefeller Institute stock and about one thousand progeny per month for more than fifteen years. The fertility, duration of life, weight, appearance and general health of these animals are excellent and have become standard. Another diet used by McCollum has proved adequate for his rodent stock, and a third, a modified Steenbock ration, has likewise proved satisfactory. And yet, mice raised on the bread and milk diet are far more susceptible to *enteritidis* and *aertrycke* mouse typhoid, botulinus toxin and mercury bichloride poisoning than mice fed on McCollum or Steenbock formulae. No intensive efforts have been made thus far to analyze these differences beyond demonstrating that butter fat and cod-liver oil added to the bread and milk changed the "susceptible" into a relatively "resistant" diet. Environmental factors, other than those tested, such as exercise, fatigue and exposure, probably exert some influence on the resistance mechanism of the host, but as yet have not been submitted to adequate tests.

The known specific components of resistance appear to be acquired as a result of contact with the specific agent. Just how potent these specific components may be and how important epidemiologically they may prove has not been determined. Perhaps the most complete test of these questions has been reported by Topley and Greenwood. Animals were vaccinated with killed cultures of *B. aertrycke* and exposed to infection by being placed in an infected population. The amount of protection conferred was claimed to be significant only when a certain type of flagellar vaccine was employed, and then only when the exposure was mild and of brief duration. The protection was not a permanent one; it was noted during periods of about ten to thirty days after exposure.

Thus far, the analyses of host resistance to infection have shown that individual animals exhibit definite amounts of non-specific inherited resistance to primary infection which take the form of a frequency distribution characteristic of the breed or race. Moreover, this resistance may be added to or detracted from by environmental influences, such as season and diet, and may be supplemented by specific immunity components acquired as a result of contact with the specific microbic agent.

The effect of the resistance factor on the spread of infection proved to be important. In the first place, when individuals of a group were given the same dose of organisms of a certain virulence, they died at varying intervals depending upon individual dif-

ferences in non-specific resistance. Moreover, when a similar group suffered a spontaneous epidemic under controlled conditions, they died at intervals similar to those in the experimental group, indicating that in both instances the form of the epidemic curve was probably controlled largely by the same factors, namely, differences in individual resistance to a large dose of organisms of stable virulence. In the second place, it became apparent that the prevalence of these infections in controlled communities was determined to a great extent by variations in population resistance.

The rôle of resistance and of virulence and dosage as well in actually inciting epidemics was studied in rabbit and fowl populations infected with Pasteurella and in mouse populations infected with Friedländer and *enteritidis* organisms. As the events in all communities were similar, the present description will be confined to those occurring in the mouse herds.

Mice constituting each population were assembled in single large cages and maintained on the routine diet of bread and milk. To each population two normal mice with identification marks were added daily. A census was kept each day and the animals found dead were removed, autopsied and cultured for the presence of the specific organism.

The first experiment was made to test the mode of spread of Pasteurella in communities previously unexposed to these organisms. Populations 1, 3 and 4 received rabbit strains; Population 2 a fowl strain. The three rabbit strains infected few of the mice and died out at once; the fowl strain behaved in quite a different manner. Eight of the ten mice originally fed died within two weeks with Pasteurella septicemia, after which no further deaths from this infection occurred for six weeks. At that time, however, one of the immigrants succumbed. Three weeks later, when the population numbered 61 individuals, explosive epidemics of Pasteurella arose, fatal to 77 per cent. of the population in five days. The epidemic then ceased abruptly and Pasteurella disappeared from the community. The virulence of strains obtained during the epidemic proved to be uniform and similar to that of the culture originally introduced into the community.

The next experiments dealt with explosive and highly fatal epidemics of Friedländer pneumonia which appeared spontaneously in the mouse populations. In the communities to which daily immigrations of two mice were discontinued, the infection died out; in the communities to which daily additions were continued, characteristic secondary waves ensued. These waves appeared when the population census reached a certain level. They lasted a relatively similar number of days and reduced the population to a similar low census. Subsequently, endemic periods intervened, followed by the disappearance of the disease in the late winter. During the next summer, epidemics broke out again similar in each population but more protracted than the previous ones. Fewer secondary waves ensued and the disease disappeared sooner. The virulence of the Friedländer organisms, as determined by their ability to spread and incite typical epidemics, in herds of previously unexposed mice, and by direct inoculation titrations during pre-epidemic, epidemic, post-epidemic and inter-epidemic phases of the infection, proved to be constant. The carrier rate increased prior to epidemic outbreaks and decreased shortly before the time of peak mortality. A substitution of relatively susceptible for standard immigrants in a given population was followed by an increase in severity and frequency of epidemics, while a reverse substitution of resistant for susceptible immigrants was followed by a fall in the severity of the infection.

The final experiments were made with *enteritidis* mouse typhoid in the same mouse populations. The infection took the form of periods of low-grade mortality, interspersed with epidemiform outbreaks. The daily deaths in the one case were either relatively constant or rhythmic in nine-day intervals; the sudden increases in mortality were invariably associated with some definite environmental disturbance. Cultures of the organisms taken from healthy carriers or mice dead of typhoid during pre-epidemic, epidemic or inter-epidemic phases of infection were of uniform pathogenicity. Furthermore, the bacterial dissociation and bacteriophage phenomena, although abundantly present, seemed to play no part in determining the spread of infection. The dosage of the organisms available to the population increased just prior to an increase in death rate and decreased in like manner before a fall in death rate. Most important were the experiments made to test the effect of changing population resistance on the prevalence of infection. Increasing population resistance by substituting an optimum for a barely adequate diet or by substituting relatively resistant for susceptible immigrants each day inaugurated periods of relatively low death rate; on the contrary, a depression of population resistance by substituting the barely adequate for the optimum diet, or the susceptible for the resistant immigrants was followed by severe epidemic outbreaks.

This concludes the present findings in experimental epidemiology. It has been noted that various phenomena of population infection can be reproduced experimentally by the proper bringing together of host and microbic factors. In these native infec-

tions, spontaneous or experimentally induced, the virulence of strains of microorganisms from different populations was occasionally different—the more virulent being the less vegetative—but the effective virulence of strains in any one community proved stable during the entire endemic and epidemic periods of observation. The dosage and host resistance factors, on the contrary, varied significantly with the amount and severity of infection. Expressing these relationships in terms of cause and effect, it appears that infections in these animal populations were controlled by stable virulence and varying dosage and resistance factors. In instances in which a foreign microorganism gained access to a hitherto unexposed population, the inherent virulence, the available dosage and the amount and distribution of non-specific population resistance together determined the extent and severity of the infection. In instances in which a microorganism was already present in the population, variations in population resistance and in available dosage were chiefly responsible for endemic and epidemic prevalences. Fluctuations in population resistance were brought about by immigration, season and diet acting upon the non-specific components, and by the infecting agent stimulating the specific components of resistance. Fluctuations in available dosage resulted from variations in the host resistance and vector factors.

To what extent is this knowledge obtained by experiment consistent with the known facts of human epidemiology? Briefly, there is evidence that the factors related to microbe and host suffice to account for the usual manifestations of cholera, typhoid and the insect and animal-borne infections; there are no data indicating that these factors may not likewise suffice in other human infections. Concerning the operation of these factors, there are grounds supporting the view that infections transmitted by vectors or contracted from foreign hosts, and infections transmitted by water, milk or food are for the most part controlled by a fluctuating dosage factor operating on a population of fluctuating resistance. These diseases, taken together and considered from the tempero-geographical view-point, constitute the great majority of the total number. Added to them are the parasitic and skin infections, whose prevalence appears likewise to be controlled by the host and dosage factors. The remaining group of respiratory diseases transmitted by direct contact, relatively very small but common to this climate, and therefore of great interest, are at present not as well understood. One can but state that the available data do not discredit the view that their prevalence too is controlled by fluctuations in dosage of and resistance to specific agents of relatively fixed virulence.

Further knowledge of the spread of human infections is being obtained by methods similar to those of experimental epidemiology. Opie's studies on the spread of tuberculosis in families, Paul's observations of families with rheumatic disease, the work on the spread of upper respiratory tract pathogens among small groups of individuals, and detailed bacteriological, clinical and sociological investigations of circumscribed communities throw light on the manner and extent of dissemination of the specific agents and the relation of variations in dissemination, that is, in dosage, to variations in amount and severity of the infection in these communities. They give promise to make more clear the rôle of resistance and whether it consists primarily of inherited non-specific factors on the one hand, or of acquired specific factors.

To broaden the scope of experimental epidemiology the studies must be extended from the acute, highly fatal, bacterial diseases of animals to the more chronic ones and to virus infections. This last step is already being taken. Knowledge of many types of infection in many species of hosts will be required for the proper development of epidemiology as a science.

# OBITUARY

## LOUIS AGRICOLA BAUER (1865–1932)

The death in Washington on April 12, 1932, of Louis Agricola Bauer, the original director and, since 1930, director emeritus of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, removes from science an internationally recognized authority in the field of his especial interest. Almost solely on account of his enthusiasm and organizing ability, the systematic magnetic survey of the whole earth both on land and on the oceans has been accomplished within the past twenty-five years, by which an empirical basis has been established for theoretical discussions of the origin and behavior of the earth's magnetic field which would otherwise have long remained impossible. While the recognition accorded Dr. Bauer rests largely on this monumental achievement in accumulating a vast amount of observational information, he has also been among the foremost in the discussion of not only terrestrial magnetism but of other related geophysical problems, as is evidenced by the long list of titles with which he is accredited.

Born of German-American parentage on January 26, 1865, in Cincinnati, Ohio, Dr. Bauer received there his early training and obtained from the University of Cincinnati the degrees of civil engineer (1888) and

master of science (1894). After a short experience as computer in the Coast and Geodetic Survey under Mendenhall and Schott, his interest in terrestrial magnetism was aroused and he entered the University of Berlin for the purpose of perfecting his theoretical knowledge of that and related subjects. Here he made the acquaintance and came under the influence of the men whose names are inseparably connected with the progress of geophysical science of that period. The subject of his dissertation for the degree of doctor of philosophy obtained in January, 1895, was "Beiträge zur Kenntniss des Wesens der Säkular Variation des Erdmagnetismus."

On his return to America he was appointed docent in mathematical physics at the University of Chicago, and the following year (1896) instructor in geophysics. Then for two years, 1897–1899, he was assistant professor of mathematics and mathematical physics at his alma mater, the University of Cincinnati. In 1899 he was appointed lecturer in terrestrial magnetism at the Johns Hopkins University. During these years his practical interest in terrestrial magnetism was manifested by the work accomplished during the summer months as chief of the Division of Terrestrial Magnetism of the Maryland Geological Survey, during which a detailed survey of the state was made, and when the Division of Terrestrial Magnetism was established at the Coast and Geodetic Survey in 1899 he was made inspector of magnetic work and chief of the division. It was under his direction in this capacity that the five magnetic observatories of the Coast and Geodetic Survey were established and put into permanent operation. At this time also preliminary experiments were made as to methods of securing satisfactory magnetic observations at sea which were to lead to large results a few years later.

Dr. Bauer's theoretical studies had emphasized the hopelessness of attempting to reach a solution of the many fundamental questions involved in the subject of the earth's magnetization until a very much wider distribution of observational results was available. He then conceived the idea of making a magnetic survey of the entire globe, and for the carrying out of this vast project applied for assistance to the newly established Carnegie Institution of Washington. His application was effectively endorsed by the leading geophysicists and magneticians of that time, the more eagerly since the nature of the organization of the institution made it an especially appropriate agency for carrying out an international project of this character. The result was the establishment in 1904 of a new Department of Research in Terrestrial Magnetism, with Dr Bauer as its first director.

During the following 25 years the carrying out of this ambitious project was vigorously prosecuted under the able and zealous leadership of the director. While those land areas were not included in the scope of the operations of the Department of Terrestrial Magnetism where the work was already being done by the governments controlling them, exploratory expeditions were sent to remote regions in Africa, Asia, Australia, South America and the islands of all the seas to make the desired observations. It was early realized that no survey confined to the land areas alone could be satisfactory either for the practical needs of navigation or for the purposes of analysis and discussion. Results of the desired accuracy could not be obtained on vessels of ordinary construction, and so an entirely unique and non-magnetic one, the *Carnegie,* was specially designed and between 1909 and 1929 was sent to all parts of the navigable seas collecting magnetic and oceanographic information not available by any other means yet devised.

While this work was in progress, Dr. Bauer focused attention on the fundamental theory of terrestrial magnetism and published a series of papers dealing with the physical decomposition, analysis and origin of the earth's magnetic field. The last one on "Chief Results of a Preliminary Analysis of the Earth's Magnetic Field for 1922," which appeared in 1923, summarized his latest mathematical analysis as based chiefly on the magnetic data obtained by the Department of Terrestrial Magnetism on land and sea. Fifteen papers, 1892–1923, on the magnetic secular variation dealt with the discussion of the phenomena and the internal and external systems of operating causes; the earth's total magnetic energy was computed by rigorous methods, based for the first time on satisfactory data, for various epochs, 1829–1885, and it was found that there has been a steady diminution in the earth's magnetization—a result confirmed by the analysis for 1922, mentioned above. Dr. Bauer also initiated magnetic and allied observations during eleven solar eclipses, beginning with that of May 28, 1900, he himself making observations during that and three others, to determine possible magnetic effects. Researches dealing with solar activity and terrestrial magnetism were published in twelve leading communications. Others related to correlations between solar activity and atmospheric electricity and the annual variation of atmospheric electricity, and to earth-currents. Space does not permit listing the many other contributions dealing with special problems.

In addition to his extensive contributions to terrestrial magnetism and allied subjects, Dr. Bauer has aided greatly in the development and progress in these fields through the publication of the *International Quarterly Journal of Terrestrial Magnetism and Atmospheric Electricity.* He founded this journal in

1896 and was solely responsible for it until 1927, since which time he has collaborated in its continuation.

In recognition of his services to science, Dr. Bauer was the recipient of many honors. The honorary degree of D.Sc. was conferred on him by the University of Cincinnati and by Brown University. He received the Charles Lagrange prize (Physique du Globe) of the Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique, the Georg Neumayer Gold Medal, and the insignia of Commander of the Second Class of the Norwegian Order of St. Olaf, and was appointed Halley Lecturer at the University of Oxford in 1913. He was also an honorary member of Sociedad Cientifica Antonio Alzate of Mexico, and of Royal Cornwall Polytechnic Society of England, and corresponding member of Göttingen Academy of Sciences, Portugal Royal Academy of Sciences, Batavia Academy of Sciences, Société de Géographie de Lisbonne, Russian Academy of Sciences, and Institute of Coimbra, Portugal.

Dr. Bauer served as United States delegate to the Brussels (1919) meeting of the International Research Council and to the Rome (1922), Madrid (1924) and Prague (1927) meetings of the International Union of Geodesy and Geophysics. During 1919 to 1927 he was secretary and director of the Central Bureau and during 1927 to 1930 he was president of the Section of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics. Dr. Bauer was a member of the International Meteorological Organization since 1928. He also took from 1917 a prominent part in the National Research Council of the United States and in the American Geophysical Union, being chairman of the latter union from 1922 to 1924.

The breadth of his scientific contacts was indicated also by the large number of scientific societies both at home and abroad of which he was a member. Among these were the American Philosophical Society, American Academy of Arts and Sciences, American Physical Society, American Association for the Advancement of Science, American Geographical Society, Washington Academy of Sciences, Philosophical Society of Washington, Deutsche Meteorologische Gesellschaft and Gesellschaft für Erdkunde zu Berlin.

It is not too much to say that the work of Dr. Bauer has had a large directive influence on the development of terrestrial-magnetic investigation during the past forty years and that the activities of the department which he founded have splendidly realized his vision.

Dr Bauer is survived by his widow, Mrs. Adelia Doolittle Bauer; a daughter, Mrs. Dorothea Weeks, of West Chester, Pennsylvania; a sister, Mrs. Caroline Bauer, of Cincinnati, Ohio, and a brother, Dr. W. C. Bauer, dean of the Engineering School, Northwestern University, Evanston, Illinois.

J. A. F.

## WILHELM OSTWALD

WITH the death of Wilhelm Ostwald there passes the last of the great triumvirate which discovered and developed the theory of solutions and the theory of electrolytic dissociation. The younger generation has a different perspective and adds Nernst's name to the list, very properly.

Three of these, van't Hoff, Arrhenius and Nernst, were really great thinkers, and Ostwald was a great protagonist and an inspiring teacher. So far as the effect on the scientific world is concerned Ostwald has been like Abou Ben Adhem. Ostwald has really outlined his own great value to the world in the book entitled "Great Men."

"When the prospective genius has done his great work and has communicated it to the world, one likes to think that he can go quietly to bed and wake up famous the next morning. There are one or two cases in which that is about what has happened, as in the case of Darwin, whose fundamental book was sold out within a few weeks of its appearance. This is a very rare case, however, and belongs rather in a class by itself, because it was a piece of work which had been going on for years and which was written up because of the external reason that Wallace had reached the same general conclusion. Also, the world was to some extent ready for it.

"In the overwhelming majority of cases, the earth continues to revolve at its normal rate even when the most startling thought has been put forward, and very often the work of getting the new idea accepted is scarcely less than that of originating it. In many cases the man who had the idea is not able to get it accepted and this task falls to the lot of another man who may be less clever, but who speaks a language which makes the world conscious of the treasure which had been offered to it in obscure words."

There are plenty of illustrations in modern chemistry of the truth of these words of Ostwald. The theory of stereochemistry was developed independently by van't Hoff in Holland and by LeBel in France; but it is very much of a question whether either of these men could have got the theory accepted in any reasonable time. Nobody will dispute that the work essential to the adoption of the theory was done by Johannes Wislicenus in Germany. The experiments of Pfeffer on osmotic pressure and of Raoult on the lowering of the freezing-point were very interesting; but nobody knew just what they meant. It was van't Hoff who furnished the theoretical explanation which was lacking and who thereby

enabled Raoult and Pfeffer to get the credit which was properly due them. The theory of osmotic pressure was due to van't Hoff, the theory of electrolytic dissociation to Arrhenius, and the modern theory of electromotive force to Nernst; it was Ostwald who fought the battles which resulted in the acceptance of these views. Avogadro was put across by his countryman, Cannizzaro; Gibbs by Roozeboom and by Ostwald; Donnan by Jacques Loeb; and Darwin to a great extent by Huxley.

Ostwald was born in Riga in 1853. In 1872 he entered the University at Dorpat; his first paper was published in 1875 and his doctor thesis in 1878. In 1881 he was appointed professor of chemistry at the Polytechnic in Riga, and here began the publication of the first edition of his "Lehrbuch der allgemeinen Chemie." This was the first book to present physical chemistry as a well-rounded subject, though not under the name that it was to bear later on. This book was one of the reasons why Ostwald was called to Leipzig in 1887 to take over the chair of physical chemistry. In this same year, but before he had moved to Leipzig, Ostwald began the publication of the *Zeitschrift für physikalische Chemie*. The laboratory at Leipzig was at first a ramshackle place; but later a new building was erected. Whether in the old laboratory or the new one Ostwald was the inspiring leader in physical chemistry for the whole world for nearly twenty years. Finally, his mind went stale so far as chemistry was concerned, and he turned to philosophy. It was as a philosopher, not primarily as a chemist, that he came to the World's Fair at St. Louis.

At that time Ostwald was tremendously impressed by the beauty of the autumn leaves and he expressed a desire to paint so many pictures that he would be known as the discoverer of the American landscape. This never happened, nor did Ostwald go back to chemistry after he resigned in 1906. After the philosophy stage had passed Ostwald spent the rest of his life working on the theory of color, and it was a great disappointment to him that the Nobel prize in chemistry was never followed by a Nobel prize in physics for the work on color.

Ostwald's minor activities covered an enormous ground. The volume entitled "The Energetic Imperative" contains his suggestions as to: An international organization of chemists; a universal language; an international coinage; the proper size of a printed page; universal disarmament; the setting of type; the improvement of schools; a new type of university; German script; the development of genius; the status of women, and a new calendar.

Ostwald's gift for leadership showed itself in the way his pupils regarded him. They were literally disciples, and the influence of the Leipzig school was predominant for years in the whole chemical world. Of late years there has been a change. The fashionable thing now is the question of the kinetics of the atom and the molecule. The drift is away from thermodynamics, and one hears regrets that Ostwald did not adopt the goose-step. It is probable, however, that the pendulum has swung too far away from Ostwald and that his scientific work will be rated more highly twenty years hence.

However that may be, Ostwald did a great work and was loved and followed by many people.

Wilder D. Bancroft

## RECENT DEATHS

Dr. Roland Thaxter, emeritus professor of cryptogamic botany at Harvard University, and honorary curator of the Farlow Herbarium, died on April 22 in his seventy-fourth year.

Dr. Carl Leo Mees, physicist, president emeritus of the Rose Polytechnic Institute at Terre Haute, Indiana, died on April 20, at the age of seventy-nine years.

The death is announced at the age of eighty years of Guillaume Bigourdan, formerly director of the Bureau International de l'Heure, Paris.

J. H. L. Vogt, the geologist and lately professor of geology in the Technical School of Trondhjem, Norway, died on January 3.

Princess Vladimir Andronikoff, head of the Institute for Plant Cultivation at Hohenheim, near Stuttgart, died at Hohenheim on April 1 at the age of fifty-two years.

# SCIENTIFIC EVENTS

## THE INTERNATIONAL CONGRESS OF MATHEMATICIANS

The International Congress of Mathematicians will meet at Zurich, from September 4 to 12. The mornings will be devoted to general addresses delivered by invitation, as follows: Monday: R. Fueter, "Idealtheorie und Funktionentheorie"; Tuesday: C. Carathéodory, "Über die analytischen Abbildungen durch Funktionen mehrerer Veränderlicher"; G. Julia, "Essai sur le développement de la théorie des fonctions de variables complexes"; W. Pauli, "Mathematische Methoden der Quantenmechanik"; N. Tschebotaröw, "Die Aufgaben der modernen Galois'schen Theorie"; T. Carleman, "Sur la théorie des équations intégrales linéaires et ses applications"; Wednesday: E. Cartan, "Sur les espaces riemanniens symétriques";

L. Bieberbach, "Operationsbereiche von Funktionen"; M. Morse, "The calculus of variations in the large"; E. Noether, "Hyperkomplexe Systeme in ihren Beziehungen zur kommutativen Algebra und zur Zahlentheorie"; H. Bohr, "Fastperiodische Funktionen einer komplexen Veränderlichen"; Friday: F. Severi, "La théorie générale des fonctions analytiques de plusieurs variables et la géométrie algébrique"; R. Nevanlinna, "Über die Riemannsche Fläche einer analytischen Funktion"; R. Wavre, "L'aspect analytique du problème des figures planétaires"; J. W. Alexander, "Some problems in topology"; F. Riesz, "Sur l'existence de la dérivée des fonctions d'une variable réelle et des fonctions d'intervalle"; Saturday: G. H. Hardy, "Recent work in additive theory of numbers"; G. Valiron, "Le théorème de Borel-Julia dans la théorie des fonctions méromorphes"; W. Sierpinski, "Sur les ensembles de points qu'on sait définir effectivement"; S. Bernstein, "Sur les liaisons entre quantités aléatoires"; K. Menger, "Neuere Methoden und Probleme der Geometrie"; Monday: J. Stenzel, "Anschauung und Denken in der klassischen Theorie der griechischen Mathematik." Sectional meetings will be held in the afternoons, for the presentation of short papers. Those wishing to present such papers should send short abstracts (not more than 400 words) to the Secretary of the Congress, not later than June 15; these abstracts will be printed before the meeting and distributed there. Abstracts received after that date can not appear in the proceedings unless they are delivered before the end of the congress.

Excursions and entertainments have been arranged. All communications concerning the congress should be addressed to the International Congress of Mathematicians, Ecole Polytechnique Fédérale, salle 20 d, Zurich.

## ZOOLOGICAL SESSIONS AT THE SUMMER MEETING OF THE ASSOCIATION

SECTION F will hold sessions during the summer meeting of the Association on Tuesday, Wednesday and Thursday, June 21 to 23, at Syracuse, New York. It is planned to emphasize out-of-door zoology by field excursions and informal discussions of ecological and natural history relations. Probably excursions will be made on each of the three days, either for the entire day or shorter half-day trips to representative regions of Central New York. These excursions are expected to be joint sessions of zoologists, ecologists and botanists; leaders will be persons well acquainted with the regions visited. If there are members of the section who do not desire to participate in the out-of-door sessions, provisions may be made for the reading of papers in other fields. Those who desire to present papers should send titles to the secretary promptly. All papers will be limited to 15 minutes each and titles must be accompanied by abstracts of about 250 words giving the substance of the paper. If sufficient papers are presented they will be grouped into appropriate fields. In sending titles the field should be indicative of the group in which the paper should be read, also whether lantern or charts are to be used, and whether microscopes are needed for demonstration. All titles and abstracts must be in the hands of the secretary not later than May 20 if they are to appear in the program.

GEO. T. HARGITT,
*Secretary, Section F*

DUKE UNIVERSITY,
DURHAM, NORTH CAROLINA

## AWARD OF THE OSBORNE MEDAL TO DR. C. H. BAILEY

DR. CLYDE H. BAILEY, professor of agricultural biochemistry in the University of Minnesota and cereal chemist in charge of the section of cereal chemistry in the Division of Agricultural Biochemistry in the Minnesota Agricultural Experiment Station, has been awarded the Thomas Burr Osborne Gold Medal of the American Association of Cereal Chemists "for distinguished contributions in cereal chemistry." The formal presentation of the medal will be made at the annual meeting of the association which will be held from May 23 to 26 at Detroit.

This medal was established in 1926 by the American Association of Cereal Chemists who desired "to honor those scientists who have contributed signally to the advancement of our knowledge in this field of specialization—the award to be made only at such times as were justified by unusually meritorious contributions." The first award was made in 1928 to Thomas Burr Osborne, after whom the medal was named, for his classic studies in the field of plant proteins in general and the proteins of the cereals in particular. Dr. Bailey will be the second recipient of the Osborne medal.

Dr. C. H. Bailey was born in Minneapolis in 1887. He received his B.S. degree from North Dakota State College, the M.S. degree from the University of Minnesota, and the University of Maryland granted him the Ph.D. degree, his thesis being entitled "The Respiration of Shelled Corn." From 1907–1911 he was scientific assistant in the Bureau of Plant Industry, U. S. Department of Agriculture, where again his field of work was cereal chemistry. Since 1911, except for minor interruptions, he has been continuously associated with the Division of Agricultural Biochemistry at the University of Minnesota.

Dr. Bailey was an active member and officer of the American Society of Milling and Baking Technology,

the society which was merged with the American Association of Cereal Chemists in 1923, and played a conspicuous rôle in the federated society. When in 1923 it was decided to establish a new scientific journal, *Cereal Chemistry,* as the official publication of the society, Dr. Bailey was selected as editor-in-chief and he served this publication in that capacity during the period 1924 to 1931.

Dr. Bailey is the author of more than a hundred bulletins and papers published in scientific journals. These papers range in content over the entire field of cereal chemistry, including fundamental studies in grain storage, grain grading, milling, the storage of milled products, the evaluation of quality of flours, the process of dough fermentation, the effect of individual constituents in the dough batch, physico-chemical factors in flour and bread manufacture, the baking test, including both the test loaf and its commercial applications, the storage of baked products, rancidity of fats and oils used in baked products, and methods of analysis of cereals and cereal products.

### THE AMERICAN PHILOSOPHICAL SOCIETY

At the annual meeting of the American Philosophical Society, held in Philadelphia on April 21, 22 and 23, the following members were elected:

Dr. Edward Goodrich Acheson, chemist, St. Petersburg, Florida, formerly president of the Electro-chemical Society.

Dr. Edward Cooke Armstrong, professor of French, Princeton University.

M. Gilbert Chinard, Department of French Literature, the Johns Hopkins University.

Dr. Ralph Erskine Cleland, professor of biology, Goucher College.

Dr. Arthur J. Dempster, professor of physics, University of Chicago.

Dr. Arnold Dresden, professor of mathematics, Swarthmore College.

Dr. Herbert Fox, professor of comparative pathology, University of Pennsylvania.

Dr. Edwin Francis Gay, professor of economic history, Harvard University.

Dr. George Lincoln Hendrickson, professor of Greek and Latin literature, Yale University.

Dr. Edwin Walter Kemmerer, professor of international finance, Princeton University.

Dr. Thomas William Lamont, New York.

Dr. Arthur Oncken Lovejoy, professor of philosophy, the Johns Hopkins University.

Dr. Elmer Drew Merrill, director of the New York Botanical Garden.

Dr. John Raymond Murlin, professor of physiology and director of department of vital economics, University of Rochester Medical School.

Dr. Charles P. Olivier, professor of astronomy and director of the Flower Observatory, University of Pennsylvania.

Dr. Ernest Minor Patterson, professor of economics, Wharton School of Finance and Commerce, University of Pennsylvania.

Dr. Henry A. Sanders, professor of Latin, University of Michigan.

Dr. Jacob Richard Schramm, editor-in-chief of *Biological Abstracts.*

Dr. Charles P. Smyth, associate professor of chemistry, Princeton University.

Dr. Edward Lee Thorndike, professor of psychology and director of the division of psychology, Institute of Educational Research, Teachers College, Columbia University.

Dr. Richard Chace Tolman, professor of mathematical physics, California Institute of Technology.

Dr. Henry Van Peters Wilson, Kenan professor of zoology, University of North Carolina.

Dr. Sewall Wright, professor of zoology, University of Chicago.

Foreign members elected were:

Ramon y Cajal, Madrid.
Dr. William H. Collins, Canada.
Professor David Hilbert, Göttingen.
M. Emmannuel de Margerie, Paris.
Dr. Ivan Pavlov, Leningrad.

Mr. Roland S. Morris, formerly United States Ambassador to Japan and member of the Philadelphia bar, was elected president. He succeeds Professor Henry Norris Russell, of Princeton University. Dr. James H. Breasted, Dr. Elihu Thomson and Dr. Edwin G. Conklin are the vice-presidents; Dr. Arthur W. Goodspeed and Dr. John A. Miller, secretaries; Dr. Albert P. Brubaker, curator, and Dr. Eli Kirk Price, treasurer. Dr. Cyrus Adler, Dr. Henry H. Donaldson, Dr. Herbert S. Jennings, Mr. William L. Phelps and Dr. Heber D. Curtis were elected members of the council.

## SCIENTIFIC NOTES AND NEWS

Dr. Phoebus A. Levene, member of the Rockefeller Institute for Medical Research, has been elected a member of the Deutsche Akademie der Naturforscher zu Halle, on the occasion of the celebration of the centenary of the death of Wolfgang von Goethe.

Dr. J. C. Th. Uphof, head of the department of biology and professor of botany at Rollins College, was recently elected a corresponding member of the Bulgarian Botanical Society and of the Royal Netherlands Agricultural Society.

Dr. Dukinfield H. Scott, the British paleobot-

anist, has been elected a member of the Prussian Academy of Sciences.

M. C. CANTACUZENE, of Bucharest, and M. Emile Guyénot, of Geneva, have been elected corresponding members of the Paris Academy of Sciences in the section of anatomy and zoology.

PROFESSOR G. ELLIOT SMITH, professor of anatomy in University College, London, has been given the honorary degree of M.D. by the Egyptian University, Cairo, on the occasion of its first convocation, held on February 27. Professor Elliot Smith was at one time professor of anatomy in the Government Medical School, Cairo.

DR. WILLIAM LAWRENCE BRAGG, professor of physics at the Victoria University of Manchester, has been elected a member of the Athenæum, London, under a provision which empowers the annual election by the committee of a certain number of persons of distinguished eminence in science, literature, the arts or for public service.

THE presentation of the Faraday Medal of the British Institution of Electrical Engineers was made to Sir Oliver Lodge at a meeting of the institution on April 23. On this occasion Sir W. E. Sumpner delivered the twenty-third Kelvin Lecture on "The Work of Oliver Heaviside."

THE Messel Medal of the British Society of Chemical Industry has been awarded to Sir William Pope, professor of chemistry and director of the chemical laboratories at the University of Cambridge.

THE British Dyers' Company Gold Research Medal for the period 1930–31 has been awarded to Professor F. M. Rowe, head of the department of color chemistry and dyeing at Leeds University, for a series of three papers on the chemical and physical effects of kier boiling on insoluble azo colors on the fiber. This is the third occasion on which Dr. Rowe has received this medal.

DR. ALFRED COX, the medical secretary of the British Medical Association, will retire this year, after having held his office for twenty years. To mark their appreciation of his services, the members have raised a testimonial fund, out of which the association has been provided with an oil painting of Dr. Cox, by Sir Arthur Cope, R.A. Dr. Cox will receive a book containing the names of the subscribers, and a check. The portrait is now at the Royal Academy.

DR. ROBERT G. AITKEN, director of the Lick Observatory of the University of California at Mount Hamilton, with Mrs. Aitken, is now on his way to England where he will receive next month the gold medal of the Royal Astronomical Society.

DR. EARLE R. HEDRICK, professor of mathematics and chairman of the department of mathematics at the University of California at Los Angeles, has been named by the French government as "Officier d'Academie" "for services rendered to the cause of culture and science."

DR. ROBERT TAFT, professor of chemistry at the University of Kansas, was elected president of the Kansas Academy of Science at its recent meeting at McPherson College.

M. LOUIS MANGIN, who recently retired as director of the Museum of Natural History, Paris, and as professor of cryptogamic botany, has been elected honorary director.

DR. DENNETT L. RICHARDSON has been elected superintendent of health at Providence, Rhode Island, to succeed Dr. Charles V. Chapin, who recently retired after forty-eight years' service. Dr. Richardson is superintendent of the Providence City Hospital, the name of which has been changed to the Charles V. Chapin Hospital.

AT a meeting of the Connecticut State Dental Association, March 30, Dr. Milton C. Winternitz, dean of the Yale University School of Medicine, New Haven, was presented with the Newell Sills Jenkins Memorial Medal for meritorious service to the dental profession. The medal is awarded each year to the person who has made a notable contribution to dentistry, science or humanity. It has been awarded annually since 1922.

DR. E. L. NIXON, professor of plant pathology at the Pennsylvania State College, has been given the award of the Philadelphia Society for Promoting Agriculture "in recognition of his outstanding achievement in making practical, and within reach of all, a method whereby the production per acre of potatoes has been so remarkably increased, thereby conferring upon his fellow citizens of this and other states, who may be interested in this industry, a benefit of great and lasting value."

DR. W. REID BLAIR, director of the New York Zoological Park, was the guest of honor on April 15 at a dinner given by the employees of the park in celebration of his thirtieth anniversary as an official at the park. Dr. Claude Leister, curator of educational activities, presided. Mr. Cyril J. Newman, representing the employees, presented to Dr. Blair a gold watch engraved with his record of service in the park.

DR. THOMAS S. ROBERTS, professor of ornithology and director of the Museum of Natural History at the University of Minnesota, recently completed his work on "The Birds of Minnesota." Publication of the work has been made possible through the estab-

lishment of the Thomas S. Roberts fund by citizens of Minneapolis. Proceeds from the sale of the book will become a permanent trust fund for the Museum of Natural History, of which Dr. Roberts has been head for the past seventeen years.

Dr. Peter Hervy Buck, of Honolulu, has been appointed Bishop Museum visiting professor of anthropology. He will give instruction next year at Yale University and direct research in the problems of the Pacific area under the terms of the agreement by which Yale and the Bishop Museum of Honolulu are affiliated.

Professor C. K. Ingold, professor of organic chemistry at the University of London, is visiting Stanford University for the spring quarter. He is giving a course of lectures on "Organic Reactions," which are being considered from an electrochemical viewpoint based on the electronic theory of valency.

Professor George F. Bateman has been appointed acting dean of engineering at Cooper Union, New York City. He succeeds the late Dean Francis M. Hartmann, who died recently after thirty years of service on the engineering faculty. Assistant Professor Norman L. Towle has been promoted to a full professorship in charge of the department of electrical engineering.

Promotions to professorships in the University of California include S. B. Freeborn, in entomology; Tracy I. Storer, in zoology; H. S. Smith, in entomology; R. B. Brode, in physics; and in the Medical School, San Francisco, F. S. Smyth and I. M. Thompson, in pediatrics, and R. O. Moody, in anatomy.

Dean Hugh P. Baker, of the School of Forestry, Syracuse University, has been appointed a member of a committee organized by the Association for the Protection of the Adirondacks in connection with promoting a public protest against the recreational amendment to the Constitution of the State of New York which provides for cutting timber on the forest preserve lands to make clearings for entertainment structures, which will come up for ratification by the people next fall.

Dr. Oliver Justin Lee, associate professor of astronomy at Northwestern University, will make observations next summer at Fryeburg, Maine, with the aid of airplanes and captive balloons to find out the changes in the temperature and pressure in the air at a series of specific altitudes during the total eclipse of the sun on August 31. Aerological instruments will be placed in the airplanes and captive balloons to record the changes. Three or four balloons will be used in the first 1,000 feet of altitude. Commercial airplanes will be held at 3,000, 8,000 and 15,000 feet, and Professor Lee is negotiating with the United States Navy for a special navy plane to operate at 25,000 or 30,000 feet. The airplanes will arrive at their specified levels at least half an hour before the eclipse and will fly at easy cruising speed until the eclipse, which will last ninety-nine seconds, has passed. Dr. C. F. Marvin, chief of the United States Weather Bureau, who will provide the aerological instruments and assist in decoding the records, and Rear Admiral Walter B. Gherardi, hydrographer of the United States Navy, will probably accompany Professor Lee to Fryeburg. Captain Barnett Harris, of the United States Army Signal Service, photographer of eclipses, will also be with Professor Lee. He will have with him a battery of four motion-picture cameras equipped with special lenses and will if possible make a complete motion picture of the eclipse.

Dr. Frank Aydelotte, president of Swarthmore College, who is visiting Mexico City, is leaving for Germany, where he will study biological research laboratories. Swarthmore College has received an anonymous gift of $900,000 for the erection of a biological laboratory in memory of Dr. Edward Martin, formerly head of the U. S. Health Department. The building will cost $200,000 and the balance will be used for equipment and endowment.

Dr. Wilhelm Blaschke, professor of mathematics at Hamburg, is making a lecture tour during 1932. He will lecture at the University of Chicago and other American universities and at the Universities of Annamalai and Calcutta, India, and the Universities of Tokyo and Sendai, Japan.

Dr. Robert A. Millikan, of the California Institute of Technology, gives the first James Arthur Foundation Lecture at New York University on April 29. His subject is "The Historical Aspects of Time Measurements and their Significance in the Development of Science."

The Edgar F. Smith Memorial Lecture will be delivered in the Harrison Laboratory of Chemistry of the University of Pennsylvania on Friday, May 20, at 4 o'clock. The lecturer will be Professor Louis Kahlenberg, of the University of Wisconsin, who will speak on "The Relationship between Electrical Potentials and Chemical Activity."

Dr. A. E. Kennelly, professor emeritus of electrical engineering at Harvard University, gave the second Joseph Henry Lecture on "The Work of Joseph Henry in Relation to Applied Science and Engineering" before the Philosophical Society of Washington on April 23.

Mr. Aldous Huxley will deliver the Huxley Me-

morial Lecture at the Imperial College of Science and Technology, London, on May 4. The subject of the lecture will be "Huxley as a Literary Man."

THE Psi chapter of Sigma Pi Sigma, honorary physics fraternity, was installed at Purdue University on April 12. Dr. Marsh W. White, of the Pennsylvania State College, executive secretary, and Dr. M. N. States, of the Central Scientific Company, national president of the fraternity, were the installing officers. After the twenty-seven charter members of the chapter were initiated the new chapter conferred honorary membership upon Dr. Cornelius Lanczos, professor of mathematical physics at the University of Frankfort, Germany. Dr. Lanczos is visiting professor at Purdue University. After the installation dinner an open meeting of the chapter was addressed by Dr. Lanczos, who spoke on "Maxwell, and his Influence on Modern Magnetic Theory." The installation of the Purdue chapter brings the roll of chapters of Sigma Pi Sigma to twenty-three.

DR. CARL E. SEASHORE, dean of the Graduate College, State University of Iowa, gave the initiation address at the annual initiation of the Iowa Chapter of Sigma Xi on April 27, speaking on "The Scholar as a Person." The initiation included 102 new members. Professor E. I. Fulmer, of Iowa State College, also participated in the initiation, speaking on "The Aims and Emblems of Sigma Xi."

THE Iowa Academy of Science will hold its forty-sixth annual meeting at Iowa State Teachers College, Cedar Falls, on April 29 and 30. Dr. James H. Lees, of the Iowa Geological Survey, will give the presidential address on "Our Underground Geology." The academy lecture will be presented by Dr. L. L. Thurstone, of the department of psychology of the University of Chicago, on "The Measurement of Social Attitudes." Section meetings for the presentation of papers in special fields of science have been provided. The Junior Academy of Science of Iowa holds its first annual convention with the parent organization this year.

THE American Association of Museums meets at Cambridge this year on May 12, 13 and 14. Eight sections of the association are arranging twenty-two special programs covering almost every branch of museum interest. There will be a conspicuous absence of formal business in order to give time in three days for these conferences, besides three general sessions, discussions, entertainment and a banquet at the Fogg Art Museum. Several distinguished guest-speakers, including President Lowell, of Harvard, will be present. Headquarters will be the Commander Hotel. Reservations should be made at once. The special rate is $2.50 a day per person. Applications for double rooms with bath are urged to conserve accommodations. Reduced railroad fares have been granted on the certificate plan.

# DISCUSSION

## THE FIELD NATURALIST IN THE FINAL INTERPRETATIONS OF LIFE

NOTHING seems more obvious to me than the fact that the livingness, the behaviors of life are externalities which must eternally be interpreted in their own terms and magnitudes. Advance inward a fraction beneath the surface, and all the familiar externalities of life vanish. One encounters, then, infinite levels of action and interaction from the surface to the electronic depths. As we recede from the surface view of life, we meet ever-expanding planes of complexity until an organism in terms of its electrons or free energies or anything else from the ultra-physical point of view must mean nothing but a vast realm and play of restless force approaching immateriality, call it what we will. Chemistry represents but one small level of analysis, physiology another, morphology another, electro-magnetic behaviors another, *ad infinitum,* until the molecules, atoms and spinning electrons themselves are reached, and the personal warmth and touch of life is no more.

It is legitimate to ask: Why stop at any level, the most superficial, in this weird organic complex with the external behaviors of life at one end and vast electronic depths at the other? Cellular studies seem simple enough, but what of their aggregates? The bricks of the house, too, are simple units, but a study of the individuality of bricks will not help us to comprehend the art, the style of the architecture of the completed structure. One brick tells nothing, nor two nor ten nor a hundred. Nothing is seen nor felt until those commonplace bricks are built into their final orderly arrangements, and the externality of a particular form is created. Life in a sense is as fugacious as art; life is the art of organic expression, and a John Burroughs or an Alexander Wilson or a Ruskin alone will interpret the finalities of it all for us.

Life, somehow, is externally a translation upward of forces and behaviors from one level to another. The final theme of the organic complex is living expression, but there is a new, a subordinate theme for every subordinate level. The bird in the totality of its morphology and physiology builds a particular nest and sings a specific song, and it behaves thus in virtue of an infinite number of component levels of

internal interactions. Song is not to be sought in one organ or in two, constituting any one of its dissected and exposed physiological or morphological levels, nor in the complexities of any chemical level involving hydrogen-ion relations, blood plasmas or corpuscular affinities. Let us finally decide to study life in the properties of proteins, sugars, starches. We find no hint of the manifestations of life here. We will study the molecule, the atom, the electronic whirls and modes even more intensively. All well and good, but we can not expect to find any of the externalities of life in these remote depths of a bird's chemistry. There appears to be nothing to indicate the properties of atomic iron in the electronic energies of iron. Surely the properties of the iron atom do not allow one to predict the properties of any organic molecule into which iron enters as a constituent. At every point new property-levels are built up, one within or upon the other until the resultant of all is the subtle mood of living-expression, which we would all understand if we could.

To my own mind there is no hope of tracing life which is a summation-property, to any internal subordinate level beneath the bones and integuments, so to speak. I would as soon declare that the facies of life existed at one level as another, and hold that the free energy of the electrons should contain its embryo as truly as the morphologically immature embryonic configuration.

With these features in mind, I find great justification for the broader view-points of the genuine field-naturalist. Yet some look askance at him in these days of intensive specialization. The true naturalist is content to see the final resultant of all these interior interacting levels of structure and function, and in truth the final relevancies of life must be sought alone in its external features of form and expression. While the old-time naturalist has become scarce in our midst, it is simply because the newer psychology of organisms has thought to find the key to life in the internal relations of its mechanism. Henry David Thoreau, beholding the sunset with soul attuned to the beauty of it all, is as true a scientist as Leeuwenhoek bringing to light the sperm cells of life. One works on a more external plane than the other—that is all. The man studying chromosomes is content with the details of chromosomes, but if he seeks finality in their relations, he becomes for the moment a naturalist engaged with the external properties of life.

For that reason, a Thoreau studying the relation of his moods to the whip-poor-will's calling, term him poet-naturalist if you will, is a genuine out-and-out naturalist, nevertheless. The electronist, the chemist, the biophysicist, the physiologist, the morphologist, on and on are but subepidermal naturalists in their restricted fields. The true naturalist, the man who must always stand upon their isolated summations, ever transcending all the complexities of their intracellular finds, must be the old-time field-naturalist. Let him now touch his own subtle moods with the poetry and the philosophy of it all; let him stand as a complete entity before the wonders of the gods and he becomes, still more, the calm poet-naturalist in our midst, with sublimities of thought and feeling projected infinitely beyond the levels of his colleagues lost within the organizing integuments which somehow made all this possible as the final vision of life. At last, perchance, moments of mystical experience may lift the soul above mundane relations, and he will, like Wordsworth, feel close to some immanence in the universe.

> When the light of sense
> Goes out, but with a flash that has revealed
> The invisible world.

It is then that we have seen and felt infinitely beyond the confines of our own finite personalities, with a rare vision and mood that glimpses even the gods themselves. It is then that the scientist feels the reality and greatness of an infinite externality of being, it would seem, and the innate religious consciousness of man has asserted itself as the final logical outlook of life.

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## SPONTANEOUS COMBUSTION IN THE MARSHES OF SOUTHERN LOUISIANA

THE following is abstracted from my notes on observations of marsh fires of apparent spontaneous origin. My complete notes on the subject appeared in *Ecology,* Vol. XII, No. 2, April, 1931.

On August 4, 1924, shortly before noon, while hiking in a dried marsh two miles east of Mandeville, Louisiana, with a party of boy scouts, we observed the start of a fire which apparently ignited spontaneously. The muck-like soil of the marsh, as rich as 90 per cent. in combustible matter near the surface, varies from a few inches to several feet in depth. We were in the midst of an unprecedented drouth, and the water level, which normally would stand a few inches above the grass roots, was several feet below the surface, all but a few deep lagoons and the bottom of alligator holes being without water. The temperature was over 100° F. in the shade, and in the sun the heat was so intense that it was impossible for the boys to walk barefooted in the sand. A strong southwest wind, estimated at 20 to 25 miles per hour was blowing across the lake.

One of the boys called my attention to a column of smoke about a foot in diameter, rising from the marsh about one eighth of a mile in from the lake. We immediately ran to the fire to check it if possible and determine its origin, but, because of the nature of the combustible matter and the strength of the wind, it was already beyond control. As the partly dried marsh vegetation was not anywhere over 3 feet in height, no human could have been there without being seen. Although not a single fire had been observed in the marsh or near-by pine woods prior to this date, and the lake shore was uninhabited for about 15 miles to the eastward, we observed quite a number of large fires scattered over that area during that afternoon, which I could not attribute to accident or design by human agency. They were not along the lake shore, highways or byways where one on foot, horseback or automobile would have been apt to set them, nor along the shores of bayous where one traveling by boat would be likely to set them. A single person could not have covered the territory, even upon horseback, in a day, and the nature and depth of the muck, with the occasional bayous, would make travel by horseback impractical if not impossible.

Looking at the physical facts in the case, we find existing at the time some of the same conditions which bring about the spontaneous heating and ignition of agricultural and industrial products, combined with such weather conditions as always accompany the most disastrous forest and grass fires. That summer, similar rather sudden epidemics of fires occurred in muck soils in drained lands near my home in New Orleans. In one case I noticed what appeared to be a very small fire breaking out on the side of a stump in an empty lot, and I secured a bucket of water to extinguish it. It really took several buckets, for the fire had burned a large hole in the muck soil, and the condition of the under side of the cypress stump showed that it had been burning for some time in a partly smothered condition, and was only breaking through to the surface when observed. During a similar interval, a fire started with a match or cigarette would have set all the dried weeds and grass in the lot in flame and would not have burned the ground so deeply under the stump before spreading. Of course, because of the almost continued presence of people on the outskirts of New Orleans, I would have hesitated to attribute any of these fires to spontaneous ignition, had I not been an eye-witness to the fire in the marsh near Mandeville on August 4.

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## RHYTHMIC PHENOMENA IN GELS

IN a paper which was presented at the Buffalo meeting of the American Chemical Society (April, 1919), but which was not submitted for publication, the writer demonstrated the musical vibration and rhythmic splitting of silicic acid gels. The former of these two phenomena was also demonstrated at the same meeting[1]; the second phenomenon was recently described in great detail.[2] A third phenomenon, which the writer also reported and which does not appear to have been observed since, is the variation of pitch with time, which precedes the fracture of the gel. After silicic acid gel sets, it produces a low musical note which increases in pitch, with time, at a varying rate. Sometimes the change is too rapid to be followed and again it may be so slow that the change from the lowest to the highest pitch can be followed through all the intervening tones for a period of several days. Sometimes the pitch at the time of fracture is too high to be heard and again the fracture may occur at some lower note.

Another phenomenon which the writer observed was the production of overtones by gels contained in tubes having an irregular shape.

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## BEHAVIORISM IN SCIENCE

PSYCHOLOGY has borrowed much and learned more from the older sciences. It has thus come by method, instrument, procedure and attitude toward the problems of investigating that aspect of nature known as mental life. Mental life is now regarded as part and parcel of nature in general, not as something added or superposed on nature. This has been a great advance, but one which is yet not fully realized by all thinkers.

There has been much ado both within and without psychology over the term "behaviorism." Those to whom the term applies are either extolled as epoch makers in psychology or condemned as destroyers of mental life. Judging from the amount of discussion for and against behaviorism, one would suppose that it was something new on the intellectual and scientific horizon. Perhaps it is not. Behaviorism is an age-old concept or method. Although not specifically called by that name it has been taken for granted in all sorts of inquiries, even in the biological sciences, to which group psychology belongs. Why, then, has its advent caused such a furor in psychology or,

[1] H. N. Holmes, W. E. Kaufmann and H. O. Nicholas, *Jour. Am. Chem. Soc.*, 41, 1329, 1919.
[2] E. C. H. Davies, *Jour. Phys. Chem.*, 35, 3618, 1931.

better, why has its advent in psychology caused such a furor?

We are frequently reminded that psychology is a young science—not far removed from the parent philosophy and it must be remarked that this attitude with respect to behaviorism, both on the part of "believers" and "non-believers," is eloquent testimony as to its immaturity. This is not saying that behaviorism is this or that but merely that some psychologists and others are as yet in a state of mind which might be labeled semi-scientific and semi-philosophical with respect to the investigation of mental life. Scientifically, their thinking is belated.

If we consider the history of scientific effort and investigation since the beginning of man's curiosity about the world and himself we find that he has been observing behavior and recording its uniformities and irregularities. To make it intelligible he has invented theories and constructed hypotheses and scientific laws which are nothing more or less than statements of uniformities in behavior. The chemist looking at a precipitate in a test-tube, Newton regarding the falling apple, if the story is true, were observing behavior. So, too, each in his own sphere—the geologist, the physiologist and the biologist. No one says uncomplimentary things about these scientists because they study the behavior of certain aspects of nature and are thereby behaviorists in so far. Why, then, should the psychologist incur the anathemas of various and sundry, including some of his own relations?

Behaviorism may be right or it may be wrong, but it is no more so in psychology than in any other science. The confusion arises because oftentimes the psychologist and those interested in psychology try to be or try to do two things at the same time, with the result that neither is done well. They confuse fact and purpose, finite and infinite, uniformity and teleology, science and philosophy. Most scientists find enough to do at home and are content to observe, record and explain behavior as found in his own field. Not so with a considerable number of psychologists. As to the ultimate behind, beyond or beneath, they should not presume to discuss as physicists, chemists or psychologists. It is not their field. Some attempt to be philosophers as well as psychologists. Except in the case of a monumental genius the two attitudes produce nothing but confusion. The psychologists should be scientists first, last and always, leaving the ultimates to the philosophers. In the realm of intellect, it is their function to provide perspective, to evaluate findings, to correlate the results of the various sciences into a world-view as also to furnish an interpretation as to what is the meaning of the behavior of that which we investigate and observe. (If ever such a service was needed it is needed now, for the world is suffering from scientific indigestion.) This confusion of aims on the part of the psychologists is the result of an imperfect separation from philosophy really amounting to an immaturity of outlook and attitude.

The psychologist is only a scientist when he is thoroughly objective. Mental facts are observable only as the behavior of the organism. When, however, any one asserts that there is nothing but the response of the organism he is as mistaken as other pseudo-philosopher. That is how the behavioristic school has shown its youth and immaturity as much as any other school of psychology. A denial of consciousness is just as much beside the mark as its affirmation, and the behaviorist is quite as absurd as those whom he condemns. The psychologist as a scientist should do neither. He should be content to take human nature for granted and investigate his special field, just as other scientists take their special fields for granted. The finals, the interpretations, the unifyings, the harmonizing, the ultimates of all sorts and kinds come within the ken of the philosopher. If that division of labor is carried out then a self-imposed burden is removed from the psychologist and he will find time to be a scientist.

Behaviorism, then, is a scientific attitude common to all scientific endeavor, and if the psychologist takes that attitude as a scientist then he ought not to incur an odium from those whose intellect is alive. As long, however, as he mixed the factual with the purposive, confusion of thought is bound to occur both in his own mind and in the minds of others. Let him, content to be a humble scientist, let others soar to philosophic heights. As soon as psychology becomes purely objective this dualism of outlook will disappear. At present it has not reached that stage. Psychologists, by being scientists will be better psychologists, and by being better psychologists will be better scientists. Their philosophy may suffer, but that may be no great hardship.

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# QUOTATIONS

## INTERNATIONAL COOPERATION

At a Conference of Institutions for the Scientific Study of International Relations, held in Copenhagen in June, 1931, progress was made in the fundamental study of international relations, and the possibility of a systematic study of actual problems on interna-

tional relations, either on the lines of the Institute of Pacific Relations or by entrusting particular researches to individual institutions, was discussed. A study of the international implications in the relations between government authority and private economic activities of individuals and groups, with special reference to the new forms of public management, control, and supervision, national or international, direct or indirect, which have grown up since the war, and the motives and policies underlying them, is contemplated at the next conference. The possibility of a fundamental scientific study of the problem of disarmament was also suggested.

In industry, where an international outlook has become much more prevalent and the importance of scientific leadership is increasingly recognized, the possibilities visualised by General Smuts have found even more concrete expression. Sir Harry McGowan has already thrown out the suggestion of an International Council for Chemical Industry which would plan chemical industry as a world unit in regard to production, research and development. The World Social Economic Conference held at Amsterdam last August led to definite proposals for a five-year world plan which was to be based on world solidarity, the modification of national economic policy in accordance with its effect on world economy, and the pooling of losses due to the war. The plan involves a general moratorium on all war debts and reparation payments, a series of international loans and agreements in regard to markets and production, and the establishment of a World Research Council or Planning Board to stimulate thought and action in the planning and rational organization of the social and economic life of the world.

Were not scientific workers, as Ruskin remarked, "still eager to add to our knowledge, rather than to use it," the new opportunities confronting them of making a vital contribution to the solution of our present difficulties would have been seized with avidity. Not only industry but also whole sections of the nation are disposed to accept the leadership of science and to adopt a well-thought-out and comprehensive scheme of national and international reconstruction based upon an authoritative and scientific analysis of the whole situation. No such scheme can, however, be produced until scientific workers are sufficiently concerned with the economic and social consequences of their work to cooperate with industrialists and others who are imbued with the scientific outlook and capable of assessing the value of scientific method and knowledge. In such cooperation there should be adequate safeguard against the neglect or abuse of human values, which Bertrand Russell fears and depicts so vividly in his sketch of scientific society and scientific government.

There are all the signs that the age of individualism and competition is passing and will be succeeded by an age of cooperation and planning on a world scale. The danger is still acute that old prejudices may delay the transition and precipitate a conflict from which the recovery of civilization will be impossible. The existence of political prejudices in government circles should not lead us to overlook the facts that nowhere does prejudice and individualism linger more persistently than among the very scientific workers whose discoveries have made world cooperation and the renunciation of war at once inevitable and urgent. Even the difficulties and limitations on the intellectual classes and the intellectual progress of mankind directly imposed by the burden of armaments under present conditions have not sufficed to rouse general interest among scientific workers, or to induce them to make their fitting contribution in the analysis of the problem. Statesmen, indeed, need to take account of our prejudices as well as of the facts of life. Reason alone may be an incomplete guide for the control of human affairs and lead us into a tyranny which becomes intolerable to human nature because of its disregard for human values. Knowledge and leadership must be indissolubly linked if disaster is to be avoided, and to no class of the community is there a stronger challenge in the present emergency than that addressed to scientific workers to declare with a united and unequivocal voice the potentialities of science in the evolution of a better world order and the lines upon which a systematic policy can be evolved.—*Nature.*

# SCIENTIFIC APPARATUS AND LABORATORY METHODS

## INFLUENCE OF METHOD OF SHAKING ON AMOUNT OF PHOSPHATE DISSOLVED FROM SOIL BY WATER

DISCORDANT results were obtained during the course of experiments designed to determine the optimum time for shaking a soil-water suspension in order to dissolve phosphate. Much more phosphate was dissolved from sandy soils when vigorously shaken than when gently agitated. There was only a small difference in the amounts extracted from clay soils whichever method of shaking was used. This note is written merely to direct attention to the facts observed,

not as indicating intention to make a study of the subject.

The conditions were about as follows: Two grams of air-dry powdered soil with 200 cc of distilled water were placed in 500 cc wide-mouth bottles closed by rubber stoppers. After shaking the mixture for a definite time, it was filtered on ashless filter-paper on a Buchner funnel by the aid of suction. The first of the filtrate, which was turbid, was returned to the filter until it came through clear. In the clear solution, $PO_4$ was determined by the molybdenum blue method.

Two quite different shaking machines were employed. One had a reciprocal motion with a stroke of about two inches at the rate of 120 per minute. In this the bottles lay on their sides so placed that the motion was lengthwise of the bottles. Since the bottles were less than half full, their contents were rather violently agitated. The longer the time of shaking the greater was the amount of $PO_4$ dissolved from sandy soils. With clay soils time did not make so much difference.

In the other shaking machine, the bottles were placed with their longer axes perpendicular to the axis of the rotating holder in such manner that they were turned end over end at the rate of four revolutions per minute, which scarcely did more than keep the contents of the bottles mixed by very gentle agitation. After it was found that the method of shaking made much difference in the amount of phosphate dissolved, the position of the bottles in the end-over-end shaker was changed so that their long axes were parallel to the axis of the machine. In this way, the bottles were turned over by a sort of rolling motion which kept the contents in motion without violent agitation. The rotation was so gentle that an ordinary filter-paper placed in the soil suspension was not torn after two hours of agitation. In the reciprocal shaker, the filter-paper was disintegrated to pulp in a few minutes.

Results recorded in the appended table seem to indicate that about one hour's agitation in the end-over-end shaker is long enough for clay soils. With even this gentle motion, the $PO_4$ dissolved from soil 30, a fine sandy loam, increased with the length of time shaken, so that the length of time for shaking a sandy soil has been arbitrarily set at one hour, with the knowledge that slight changes in the conditions may cause considerable difference in the results. It appears probable that discordant results in the analysis of soils for various constituents have frequently been caused by differences in the method of mixing or agitating the suspension before filtering off the solution.

In this connection, it is of interest to note that workers in physical analysis of soils observe that the amount of colloidal matter extracted from some soils is increased by longer time of agitation of the suspension before making the separation.

Effect of Method of Shaking on $PO_4$ Extracted from Soils by Shaking With Water

| Kind of shaker | Time shaken | Soil numbers: Silty clays, No.'s 1c | 38 | 65 | Sandy soils, No.'s 30 | 53 | 68 |
|---|---|---|---|---|---|---|---|
| | | p.p.m. $PO_4$ in air-dry soils | | | | | |
| Reciprocal | 1 hour | 50 | 63 | 316 | 234 | 74 | 37 |
| " | 2 " | | | | 274 | | |
| End over end | | 49 | 49 | 316 | 100 | 37 | 30 |
| Rotary | 1 min. | 21 | | | | | |
| " | 1 hour | 42 | | | | | |
| " | 2 " | 45 | | | | | |
| " | ½ " | 40 | | | 58 | | |
| " | 1 " | 44 | | | 68 | | |
| " | 2 " | 43 | | | 82 | | |
| Shaken by hand once every five minutes for one hour, then filtered: | | | | | | | |
| Very gentle shaking | | | | | 57 | | |
| Violent shaking | | | | | 65 | | |

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## A METHOD OF ARTIFICIALLY FEEDING THE SUGAR-BEET LEAFHOPPER

Carter[1, 2] devised an apparatus for the purpose of artificially feeding the sugar-beet leafhopper, *Eutettix tenellus* (Baker). He pointed out that this device is also suitable for studies on the properties of the curly-top virus and for nutritional studies with sucking insects.

For certain biochemical investigations on the curly-top problem, Carter's apparatus was found to be unsuitable. It became necessary therefore to devise a method whereby the sugar-beet leafhopper and other closely related species could be fed artificially on very small amounts of solutions of known composition.

Pieces of glass tubing 1.5 cm in diameter and 2 cm in length served as the cage. One end of the cage was covered with cheesecloth, which was held securely in place by a rubber band. A section of paraffin ribbon, cut 60 microns in thickness with a microtome, was stuck to the other end of the cage after the leafhopper had been placed inside. The assembled cage is shown in Fig. 1. The animal mesentery membranes or the baudruche capping skins used by Carter were

[1] *Jour. Agr. Res.*, 34: 449–451, 1927.
[2] *Phytopath.*, 18: 246–247, 1928.

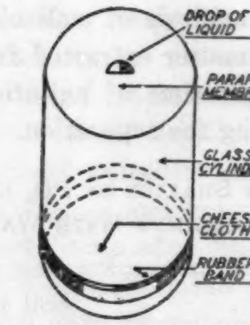


FIG. 1. Feeding device for the sugar-beet leafhopper. The insect caged in the glass ring punctures the paraffin membrane and feeds on the drop of solution.

found to be very unsatisfactory for pH determinations. When this type of membrane is wetted by liquids, adsorption of ions takes place and a serious error is introduced into the determinations. The paraffin membranes being chemically inert and easy to prepare and handle were found to be well adapted for the studies carried out.

The leafhoppers have no difficulty in getting a foothold on the paraffin membrane. There was usually a delay in finding the drop of liquid placed on the membrane if no assistance was given the leafhopper. To expedite matters, the practice was followed of waiting until the leafhopper began to puncture the membrane and then placing a drop of the liquid directly over the leafhopper. In this way it was possible to induce hungry leafhoppers to feed almost at will. The drop placed on the membrane can be protected from air and evaporation by an air-tight compartment made of the same size glass tubing. The drop can even be subjected to different gases by using such a covering chamber into which side tubes are sealed.

To study the pH of saliva injected into the drop by a leafhopper, one was allowed to feed on a drop (.01 cc) of slightly buffered 5 per cent. sugar solution. The pH determinations made on a large number of leafhoppers show that the material injected into the drop of liquid by the leafhopper is very alkaline. This was confirmed by allowing leafhoppers to feed on a drop of brom thymol blue. The drop of brom thymol blue (made acid) would turn from a lemon yellow to a deep green and in some instances to a blue color within three minutes after the leafhopper had started to feed.

In the early part of the work it was observed that some leafhoppers, while feeding, ejected a substance which very quickly coagulated around their mouth parts. To study this process another cage was designed so that it could be mounted on a slide and placed under the microscope, Fig. 2. Narrow strips were cut from the end of a micro-slide approximately 1.5 mm in thickness. Small compartments were made by sealing two such pieces parallel with each other

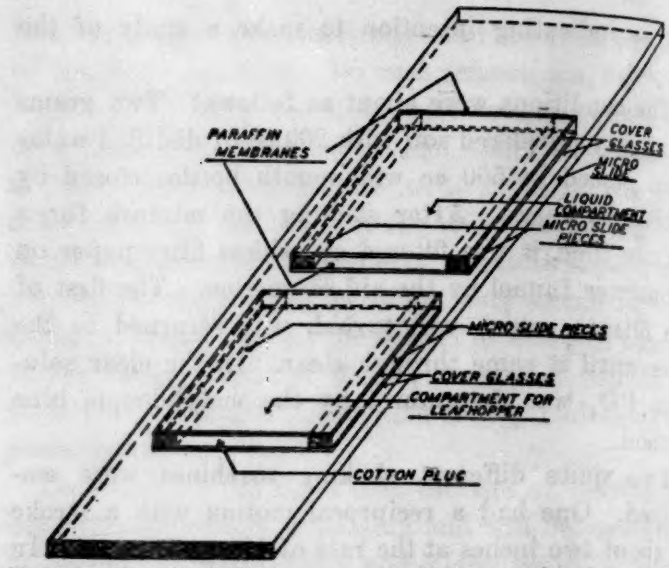


FIG. 2. Feeding device arranged to permit observation under the microscope of the sugar-beet leafhopper feeding upon the test solution.

between two square cover-glasses. Either paraffin or duco-cement may be used to seal the pieces together. A paraffin membrane 120 microns in thickness was placed across the end of one of these compartments and gently pressed in position. The liquid, on which the leafhopper was to feed, was placed in this compartment, which was then sealed with another paraffin membrane. The distortion due to the highly curved surfaces of a drop was entirely eliminated by such a compartment. The compartment containing the liquid was sealed to a glass slide with a strip of paraffin ribbon. The open end of another compartment was pushed against the membrane on the liquid compartment. This formed a cage for the leafhopper having the paraffin membrane at one end and a cotton plug at the other. With this arrangement the leafhopper was forced to feed on its side which placed its mouth parts (when through the membrane) at right angles to the line of vision through the microscope. With the leafhopper feeding in this position the mouth parts can easily be seen in action under low or high power. It is an easy matter to see the coagulable material ejected at the tip of the setae bundle.

These devices open up a wide range of interesting possibilities for study on the properties of the curly-top virus, the mechanics of feeding and the chemical nature of the leafhopper saliva. Detailed studies on the pH of the saliva of the sugar-beet leafhopper, which have been carried on as part of a study of the chemical nature of disease resistance in the case of the curly-top disease, will be presented later.

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# SPECIAL ARTICLES

## VISUAL PURPLE IN SNAKES

In the extensive literature of the visual cells of vertebrates the reptiles appear to have had less consideration than other groups. Few species have been investigated, and these few have apparently been chosen because they were easy to secure and handle rather than because they were taxonomically representative. The forms which have been studied are chiefly members of the large families, and are too closely related and too similar in habits to form a basis for sweeping generalizations concerning the retinae of reptiles as a group.

Nevertheless, such generalizations have been made and the classic pieces of comparative ophthalmological literature concur unanimously in a summary to the following effect:

Crocodiles and their relatives possess both rods and cones; geckoes have only rods, "true" lizards and chameleons only cones. All snakes (except possibly *Boa constrictor*) and all turtles have pure-cone retinae. The situation in *Sphenodon* is in dispute.

Students of the retina seem satisfied to let these statements stand in spite of the fact that rods are necessary for scotopic vision and large numbers of reptiles (most of which are snakes) have vertically elliptical pupils—a feature which herpetologists have long considered a certain indication of nocturnal habit. The writer has felt that the entire reptilian group should be resurveyed with the application of modern criteria for the distinguishing of rod from cone, and has undertaken the histological study of the light- and dark-adapted retinae of a hundred or more species of reptiles chosen with proper regard to their light-habits and to their phylogenetic relationships.

While this histological program will of course form the bulk of the writer's work upon this group, rods and cones are not always easily distinguishable in sections. Since the most essential difference between them is the presence of the sensitizer, "visual purple" in rods and its absence in cones, an investigation of the distribution of this substance in reptiles was made as a highly desirable preliminary to the histological studies.

Briefly, the presence of visual purple in a dark-adapted retina is certain proof that functional rods are present, no matter what their form as seen in sections. Although this criterion was established fifty years ago through the great work of Kühne, no one has applied it widely to reptiles in which, considering their light-habits, one would be led to expect visual purple—and hence, rods.

Visual purple has been found in nocturnal geckoes and crocodiles, but only diurnal lizards and turtles have been examined for it, with negative results, and so far as the writer knows it has not even been looked for in any snake.

The writer has employed the following technique on a number of ophidian species: the animal is left overnight or longer in absolute darkness; by ruby light the snake is etherized or decapitated and an eye is removed. The excised retina is transferred to a depression slide in normal saline and covered. This slide, in a light-tight box with a white bottom, is then brought out into diffuse daylight where, after light-adaptation of the experimenter, it is opened in the presence of one or more additional witnesses. Visual purple, if present, is seen as a distinct pink, red or lavender coloration of the preparation which bleaches in a few seconds when taken near a window.

With this method visual purple was found in the following forms: Boidae, *Python molurus* and *Boa constrictor;* Colubridae, *Tarbophis fallax* and *Dasypeltis scaber;* Viperidae, *Agkistrodon mokasen, Sistrurus miliarius* and *Crotalus horridus.* All these forms have vertical pupils, and all except *Tarbophis* represent subfamilies all members of which have vertical pupils.

In four vertical-pupilled forms no visual purple was seen; in *Trimorphodon vandenburghi* (Colubridae), *Vipera berus* and *V. ammodytes* (Viperidae) the pigment epithelium refused to separate from the bacillary layer and as a consequence the retina was black macroscopically. In *Bitis arietans* (Viperidae) this trouble was not encountered, but visual purple was not surely seen, perhaps having been bleached by the ruby light during the excessively long time required for complete anesthesia in this case. The fresh *Bitis* retina, under the microscope, showed numerous slender cells with cylindrical outer segments (assuredly rods) surrounding large, plump cells (typical ophidian cones) whose outer segments had disintegrated in the saline.

No visual purple was found in round-pupilled forms, most of which are considered strictly diurnal by herpetologists. Some round-pupilled species are secretive and crepuscular and a few are called "nocturnal" in herpetological literature; examples are *Coronella girondica* and *C. austriaca, Micrurus fulvius, Lampropeltis t. triangulum* and *Drymarchon corais couperi* (all Colubridae). All these were examined with negative results; these and other forms may prowl at night, but the duplicity theory would lead us to pronounce them incapable of vision at night. They must hunt by other senses, perhaps olfaction, which is known to be acute in snakes.

From the above, together with the facts of distribution and significance of vertical pupils in reptiles, the writer does not hesitate to make the following statement: rods are to be expected, either to the exclusion of cones or in combination with them, in all Boidae, in all Viperidae[1] and in such Colubridae as have vertical pupils. Rods should be present in the Amblycephalidae and in *Xenopeltis,* but will probably not be found in any round-pupilled Colubrid.[2]

Most ophidian *species* are diurnal Colubrids, but most ophidian *families* are, bodily, nocturnal and have vertical pupils. Thus, in spite of the generalization seen in the literature, it is probable that rods are very wide-spread in snakes and that, from the phylogenetic standpoint, it is the pure-cone retina which represents the major departure from the beaten path.

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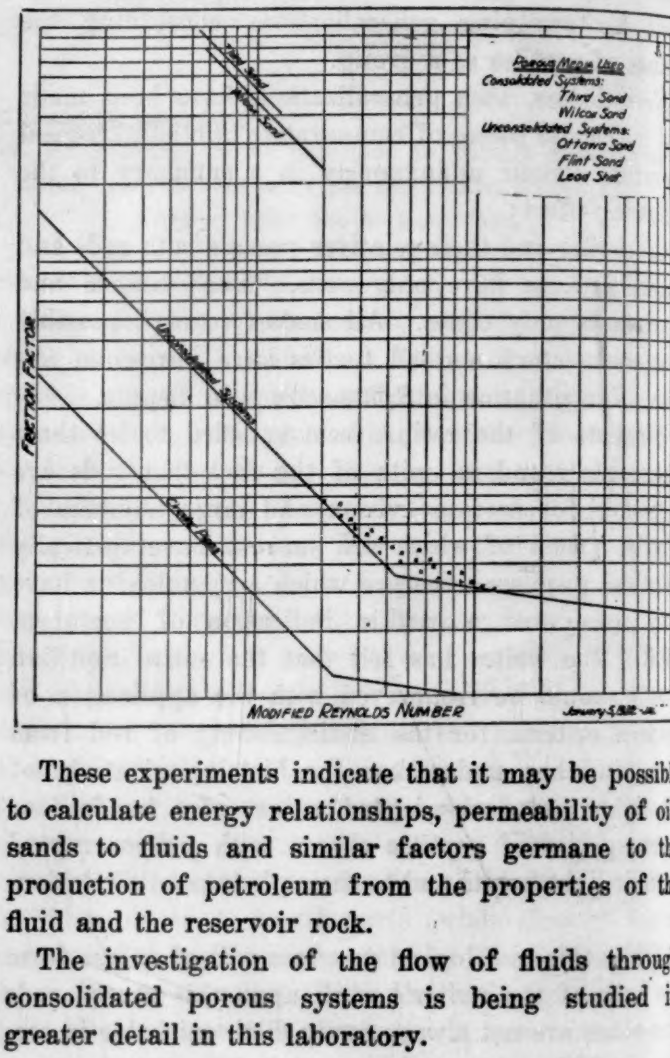
## A NOTE ON THE FLOW OF FLUIDS THROUGH POROUS MEDIA

THE flow of fluids through porous media is being studied intensively in the Petroleum Research Laboratory of the Mineral Industries Experiment Station at The Pennsylvania State College.

Over 200 tests of the flow of water, air and crude petroleum through Ottawa sand, graded flint sand and six sizes of lead shot have been made as well as a few of the flow of water through consolidated sandstones. Of the latter, samples from cores of the Wilcox sand of Oklahoma and the Third sand of Venango County, Pennsylvania, were used.

The data have been correlated with the flow of fluids in circular pipes[1] by plotting a modified Reynolds number against a friction factor. Points so plotted for all systems of unconsolidated material define within the region of viscous flow a straight line parallel to that for circular pipes. Chilton and Colburn[2] recently found this to be true for columns packed with broken solids many times greater in mean diameter than the sand systems used in this work. A break in this line, or rather a region of change, is found with sand systems for large Reynolds numbers exactly as is the case for circular pipes corresponding to the change from viscous to turbulent flow.

It is remarkable that the flow of water through the consolidated sands studied so far, defines a straight line on this chart for each sand parallel to the lines for circular pipe and unconsolidated systems. The displacement evidently must be due to differences in composition and degree of consolidation of the sands. The illustration shows the type and relative displacement of the curves.




These experiments indicate that it may be possible to calculate energy relationships, permeability of oil-sands to fluids and similar factors germane to the production of petroleum from the properties of the fluid and the reservoir rock.

The investigation of the flow of fluids through consolidated porous systems is being studied in greater detail in this laboratory.

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[1] Except possibly the primitive genus *Causus,* which some writers state to have a round pupil and to be partially diurnal.

[2] Certain of the round-pupilled Elapines, such as *Naja* sp., may prove to have rods. The Cobras and their allies are in a state of confusion as regards their light-habits, as described by various authors. Even the matter of pupil-shapes in many Elapines is unsatisfactory, for authors who have observed living specimens disagree as to whether the pupil is round or a vertical slit!

[1] Walker, Lewis and McAdams, "Principles of Chemical Engineering," 2nd ed., p. 87, McGraw-Hill Book Co., Inc., 1927.

[2] Chilton and Colburn, *Ind. Eng. Chem.,* 23, 913–19, 1930.

## BOOKS RECEIVED

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